

**CLAIMS**

What is claimed is:

1. A fuel injection system for a gas turbine, comprising:

a pilot fuel injector;

a pilot swirler for swirling air past the pilot fuel injector;

a main airblast fuel injector;

inner and outer main swirlers for swirling air past the main airblast fuel injector; and

an air splitter, located between the pilot swirler and the inner main swirler, the air splitter being so arranged and constructed to divide a pilot air stream exiting the pilot swirler and the air splitter, from a main air stream exiting the inner main swirler, whereby a bifurcated recirculation zone is created between the pilot air stream and the main air stream.

2. The system of claim 1, further comprising:

a fuel supply control system for providing fuel only to the pilot fuel injector at lower power conditions, and for providing fuel to both the pilot fuel injector and the main airblast fuel injector at higher power conditions.

3. The system of claim 1, wherein:

the main airblast fuel injector includes an atomizer filmer lip having an aft end; and

the air splitter has an aft end angled radially inboard and axially positioned upstream of the aft end of the atomized filmer lip of the main airblast fuel injector.

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4. The system of claim 1, further comprising:

an outwardly flared wall downstream of the main airblast fuel injector, the flare ending at an angle in the range of 45° to 70° to a central axis of the main airblast fuel injector.

5. The system of claim 4, wherein:

the outwardly flared outer wall has a length from an aft end of the main airblast fuel injector to an aft end of the outer wall sufficiently short to prevent autoignition of fuel within the outer wall.

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6. The system of claim 4, wherein:

the outwardly flared outer wall has a length from an aft end of the main airblast fuel injector to an aft end of the outer wall sufficiently short to prevent main fuel wetting of the flared outer wall.

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7. The system of claim 1, wherein:



the pilot fuel injector is a pressure atomizer; and  
the pilot swirler surrounds the pressure atomizer.

8. The system of claim 1, wherein:

the swirlers are constructed such that from 5 to 20% of total airflow is  
through the pilot swirler, from 30 to 70% of total airflow through the swirlers is  
through the inner main swirler, and the balance of total airflow is through the outer  
main swirler.

9. The system of claim 1, wherein:

the pilot fuel injector is a pilot airblast fuel injector; and  
the pilot swirler includes inner and outer pilot swirlers located inward and  
outward of the pilot airblast fuel injector.

10. The system of claim 9, wherein:

the swirlers are constructed such that 1 to 10% of total airflow through the  
swirler is through the inner pilot swirler, 2 to 15% of total airflow is through the  
outer pilot swirler, 30 to 70% of total airflow is through the inner main swirler, and  
the balance through the outer main swirler.

11. The system of claim 1, wherein:

the inner and outer main swirlers each include axial swirl vanes.

12. The system of claim 11, wherein:

the axial swirl vanes are curved to reduce the Sauter Mean Diameter of a

5 main fuel spray from the main airblast injector.

13. The system of claim 11, wherein:

the axial swirl vanes of the inner main swirler have a swirl vane angle in the  
range of 25 to 60 degrees; and

the axial swirl vanes of the outer main swirler have a swirl vane angle in the  
range of 45 to 65 degrees.

14. A fuel injection system for a gas turbine, comprising:

a pilot fuel injector;

15 a pilot swirler for swirling air past the pilot fuel injector;

a main airblast fuel injector;

inner and outer main swirlers for swirling air past the main airblast fuel  
injector; and

an air-splitter means, located between the pilot swirler and the inner main  
20 swirler, for dividing an outer pilot air stream exiting the pilot swirler from an inner

main air stream exiting the inner main swirler, and for thereby creating a bifurcated recirculation zone.

15. The system of claim 14, wherein:

5 the main airblast fuel injector includes an atomizer filmer lip having an aft end; and

the air splitter means has an aft end angled radially inboard and axially positioned upstream of the aft end of the atomized filmer lip of the main airblast fuel injector.

16. A fuel injector apparatus for a gas turbine, comprising:

a primary fuel injector;

a first swirler, nested about the primary fuel injector;

a second swirler nested about the first swirler;

15 a secondary fuel injector, nested about the second swirler;

a third swirler nested about the secondary fuel injector; and

an air splitter, nested between the first and the second swirler, and having a radially inwardly tapered inner surface defining an outlet opening, the outlet opening being disposed axially downstream of the primary fuel injector for creating  
20 a bifurcated recirculation zone.



17. The apparatus of claim 16, wherein:

the secondary fuel injector is an airblast, secondary injector having an annular fuel outlet and a pre-filming surface for providing an annular film of fuel to be entrained between the second and third swirlers.

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18. The apparatus of claim 17, further comprising:

a flared outlet axially downstream of the secondary fuel injector.

19. The apparatus of claim 16, wherein:

the primary fuel injector is an airblast primary injector; and

the apparatus further includes a fourth swirler nested inside of the primary fuel injector.

20. The apparatus of claim 16, wherein:

the primary fuel injector is an axially located pressure atomizer.

21. A fuel injector apparatus for a gas turbine, comprising:

an axially located pressure atomizer first fuel injector;

a first swirler located concentrically about the pressure atomizer fuel injector;

a second swirler located concentrically about the first swirler;

a third swirler located concentrically about the second swirler;

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an airblast fuel injector located concentrically between the second and third  
swirlers; and

an air splitter located concentrically between the first and second swirlers.

5 22. A fuel injector apparatus for a gas turbine comprising:

a first swirler;

a second swirler located concentrically about the first swirler;

a third swirler located concentrically about the second swirler;

a fourth swirler located concentrically about the third swirler;

10 an inner airblast fuel injector located concentrically between the first and  
second swirlers;

an outer airblast fuel injector located concentrically between the third and  
fourth swirlers; and

an air splitter located concentrically between the second and third swirlers.

15 23. A method of injecting fuel into a gas turbine, comprising:

(a) injecting a pilot fuel stream;

(b) injecting a main fuel stream concentrically about the pilot fuel stream;

20 (c) providing a swirling pilot air stream to entrain the pilot fuel stream;

(d) providing a swirling main air stream to entrain the main fuel stream;  
and

(e) splitting the pilot air stream from the main air stream and creating a bifurcated recirculation zone between the pilot air stream and the main air stream.

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24. The method of claim 23, wherein step (e) further includes:  
avoiding creation of a central recirculation zone.

25. The method of claim 23, further comprising:  
centrifuging the pilot fuel stream into the bifurcated recirculation zone by  
means of the swirling pilot air stream of step (c).

26. The method of claim 25, further comprising:  
anchoring a pilot flame in the bifurcated recirculation zone.

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27. The method of claim 23, wherein:  
step (a) includes injecting the pilot fuel stream through an axially located  
pressure atomizer injector;

step (b) includes injecting the main fuel stream through an airblast injector;

20 and



step (d) includes providing inner and outer swirling main air streams inward and outward of the airblast injector.

28. The method of claim 27, further comprising:

dividing a total <sup>airflow</sup> ~~airflow~~ between the pilot air stream and the inner and outer main air streams such that:

the pilot air stream includes from 5 to 20% of total airflow;

the inner main air stream includes from 30 to 70% of total air    flow;

and

the outer main air stream includes the balance of total airflow.

29. The method of claim 23, wherein:

step (a) includes injecting the pilot fuel stream through a pilot airblast injector;

step (b) includes injecting the main fuel stream through a main airblast injector;

step (c) includes providing inner and outer swirling pilot air streams; and

step (d) includes providing inner and outer swirling main air streams.

30. The method of claim 29, further comprising dividing a total <sup>airflow</sup> ~~airflow~~ between the air streams such that:

the inner pilot air stream includes from 1 to 10% of total <sup>airflow</sup> ~~air flow~~;

the outer pilot air stream includes from 2 to 15% of total airflow;

the inner main air stream includes from 30 to 70% of total <sup>air flow</sup> air flow; and

the outer main air stream includes the balance of total air flow.

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Year	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100
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